Communication Systems

Digital source: finite or countable set of messages

Analog source: produces messages that vary in a continuum way

A digital communication system transmits and receives messages from a digital source.

An analog communication system transmits and receives messages from an analog source.

Example communication systems

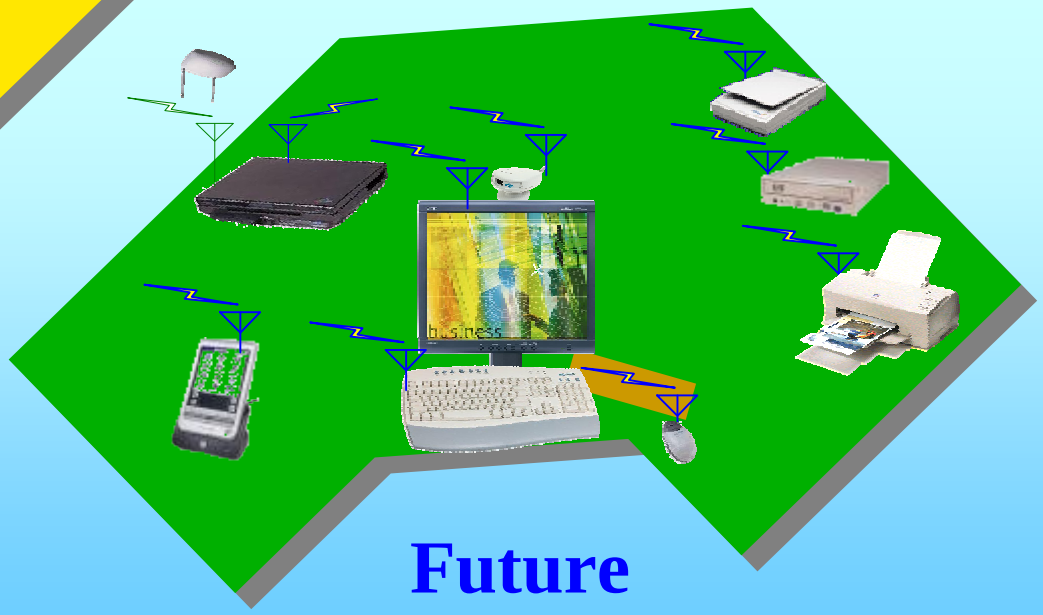
- Prehistoric: animal comm.; analog
- 4-5K years ago: written language; digital
- 1834: Gauss-Weber telegraph; digital
- 1876: Bell telephone; analog
- 1894: wireless radio; analog
- 1918: Armstrong superheterodyne receiver; analog
- 1920: Carson applies sampling in communications
- 1926: Baird-Jenkins television; analog

Example communication systems

- 1933: Armstrong invents FM; analog
- 1935: Watson-Watt radar; analog
- 1947: Bell Lab invents transistors
- 1948: Shannon published information theory
- 1958: Kilby-Noyce built integrated circuits
- 1963: Bell touch-tone phone; digital
- 1972: Motorola cellular phone; analog
- 1980: Bell fiber-optic communication; analog
- 1989: GPS
- 1990's: Internet and the digital comm era

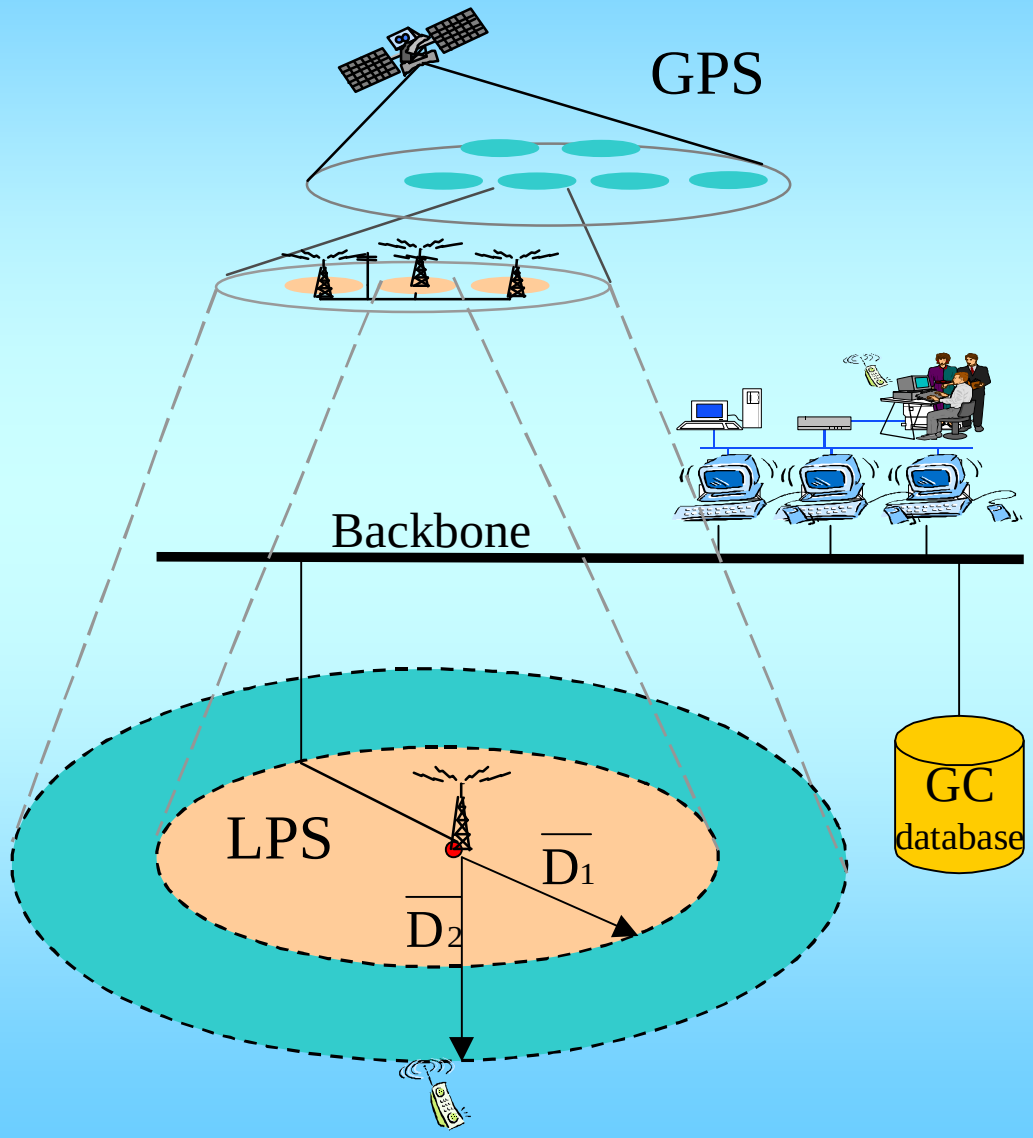
Where things are and where they are heading

Today's office

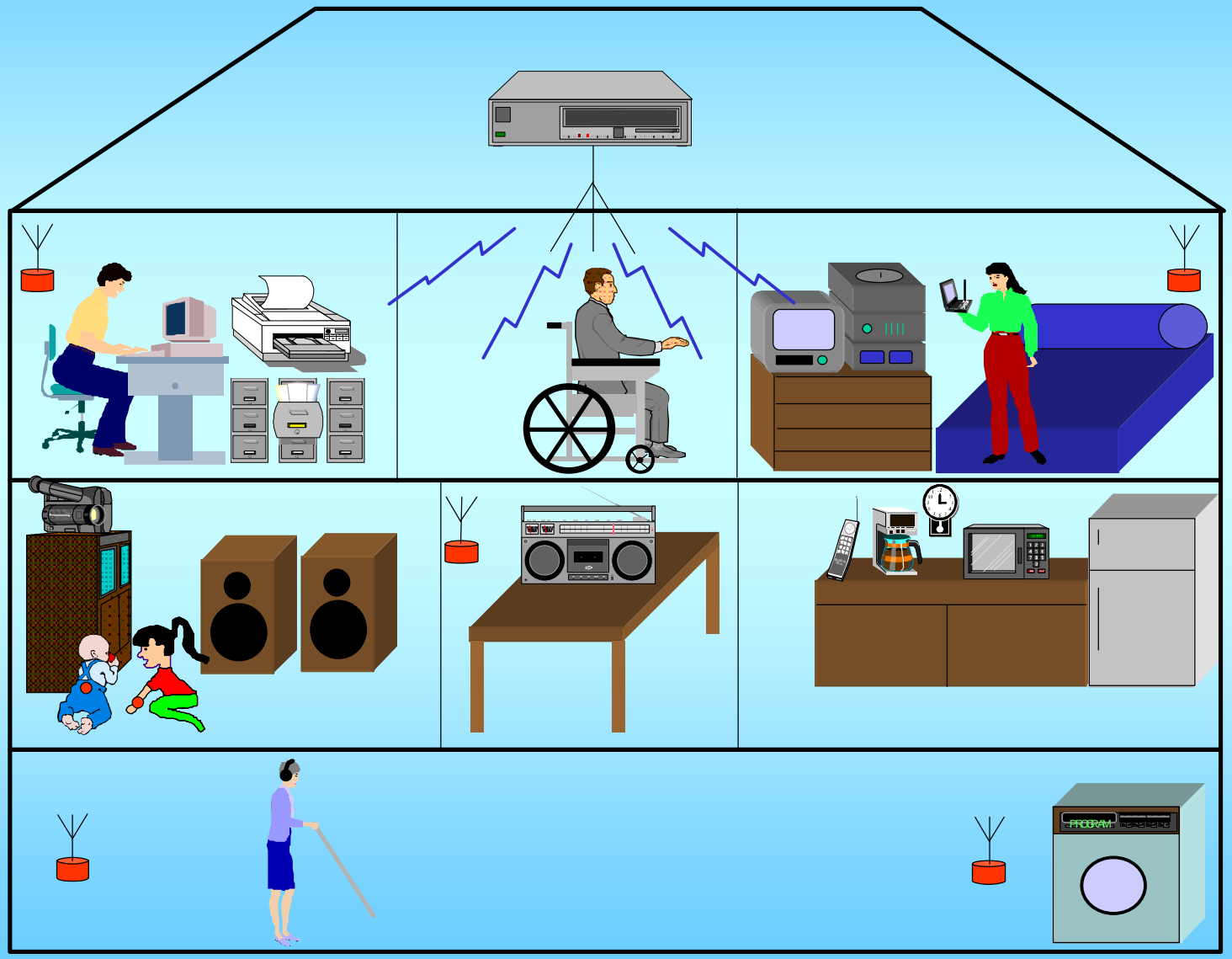


Future office

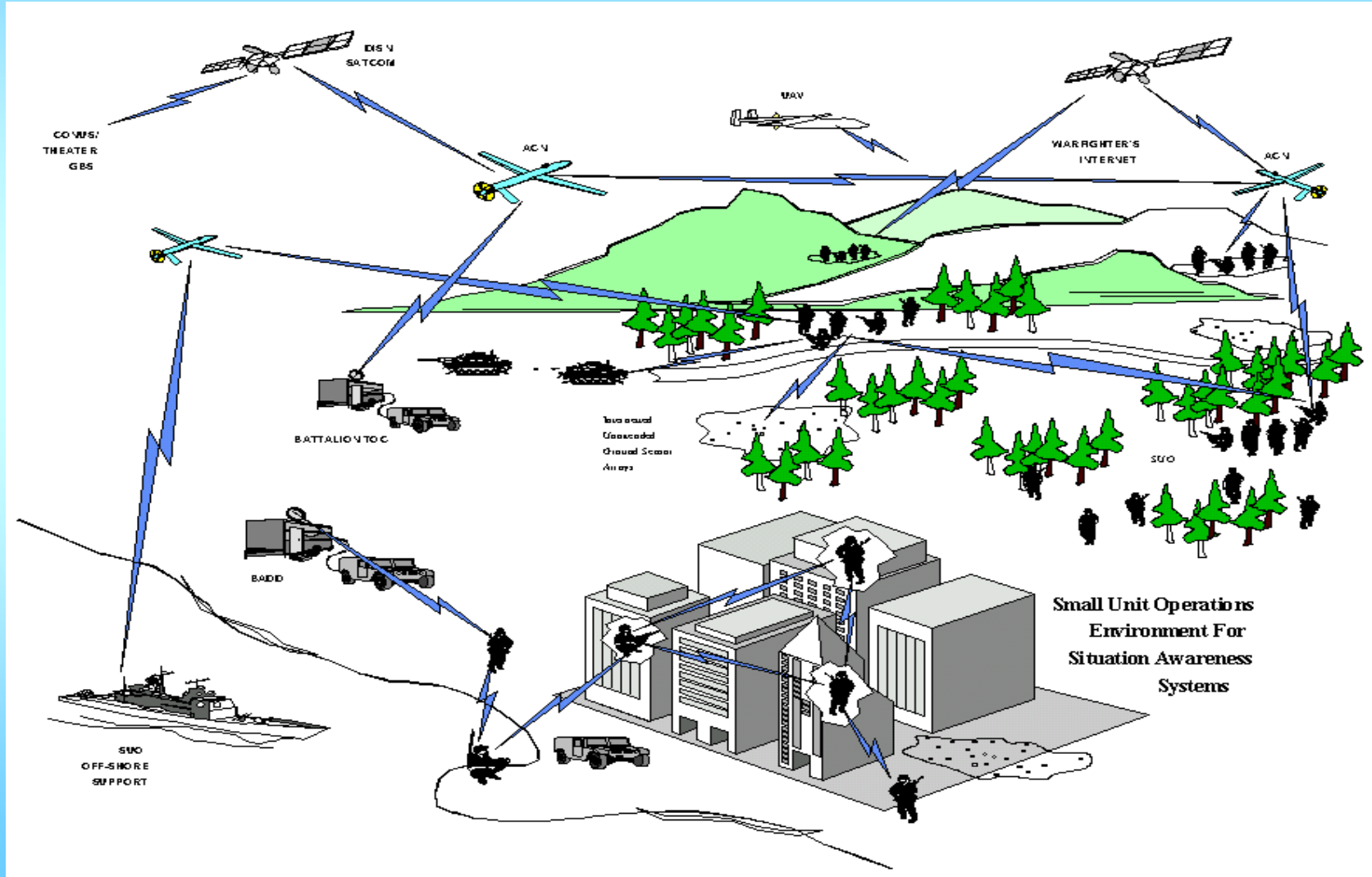
Layered Geolocation Networks



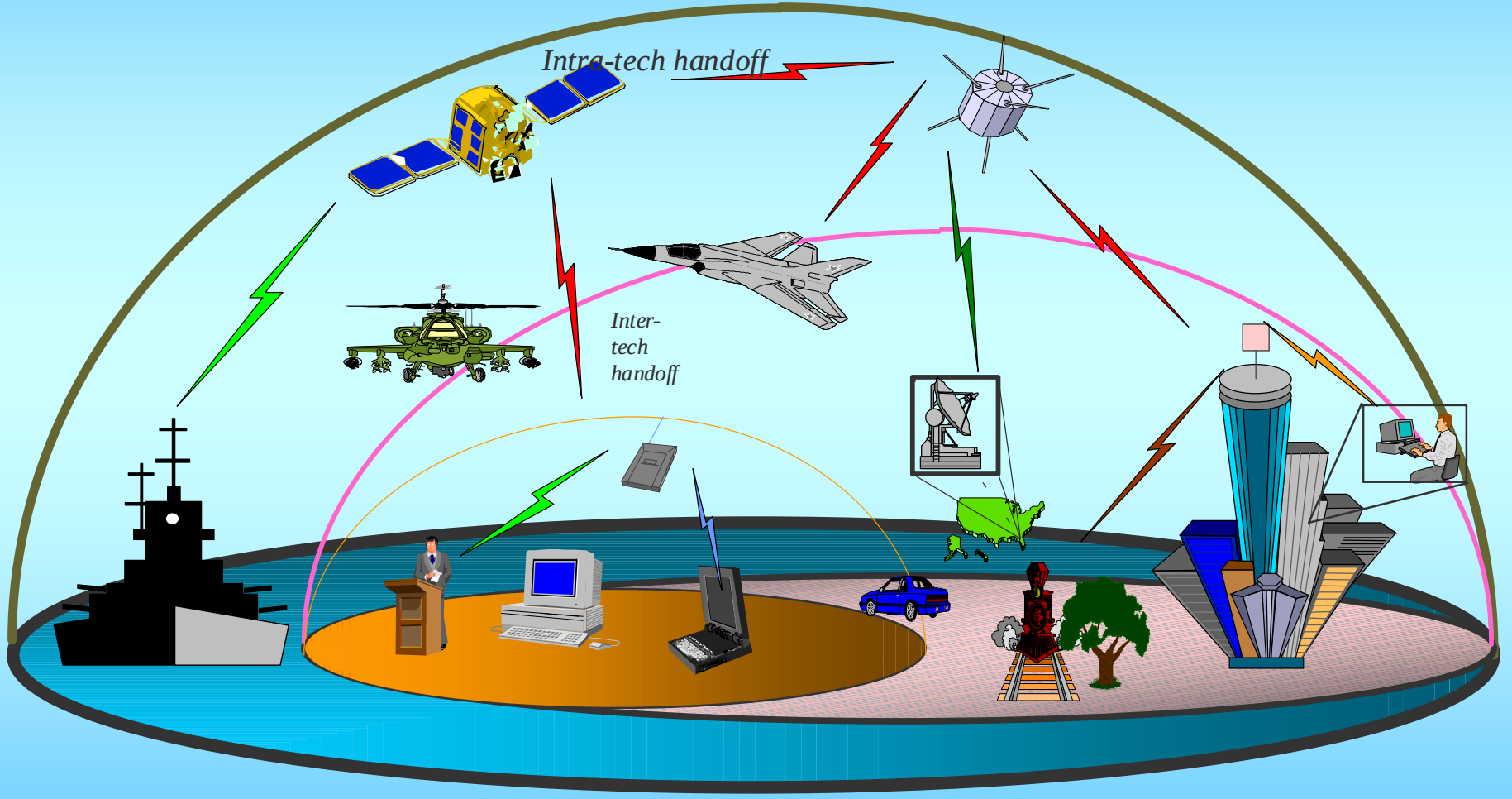
Smart Home Networks



Small Unit Operations Environment for Situation Awareness Systems (SUO-SAS)

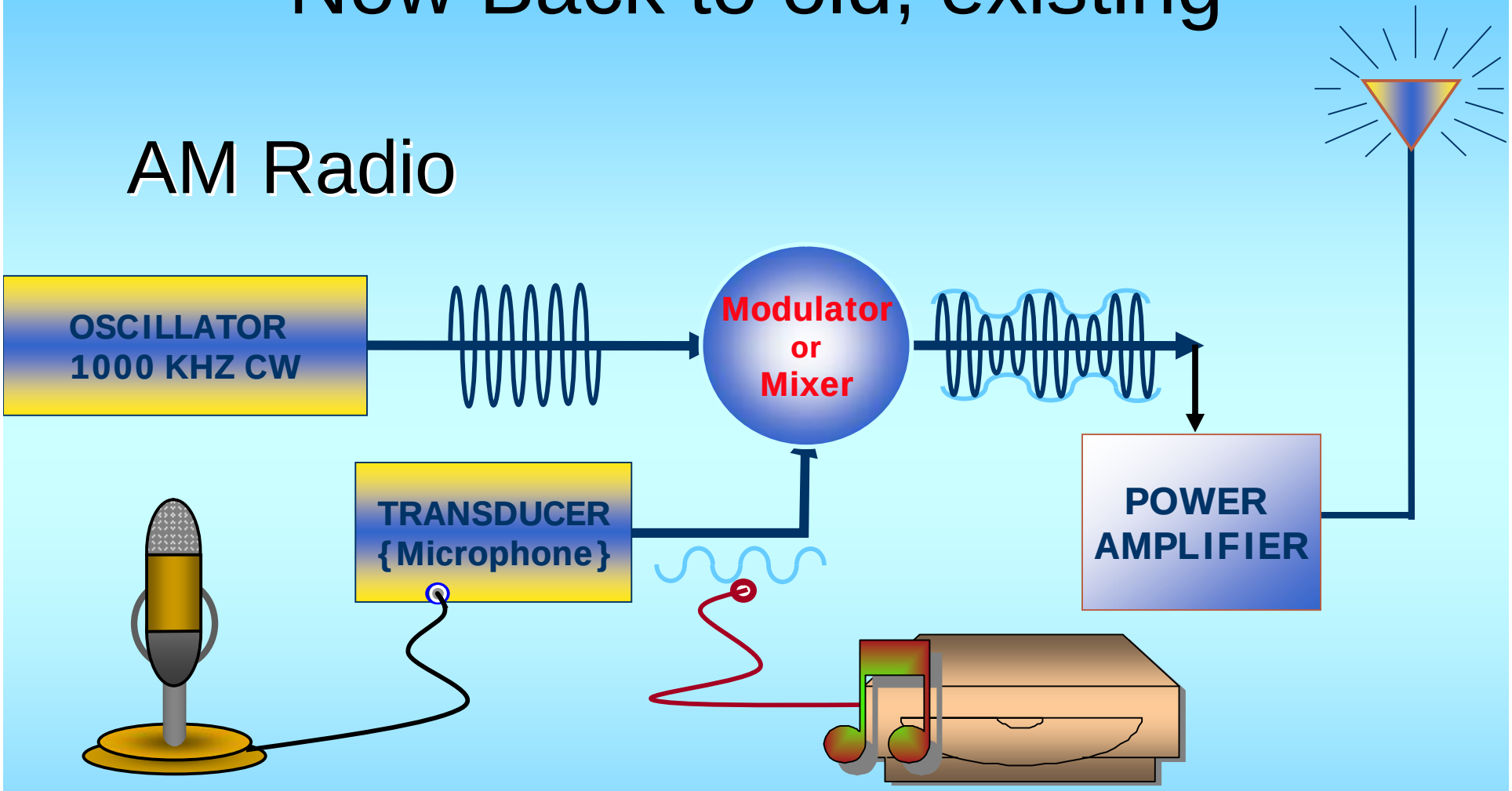


Non-Homogeneous Wireless Networks



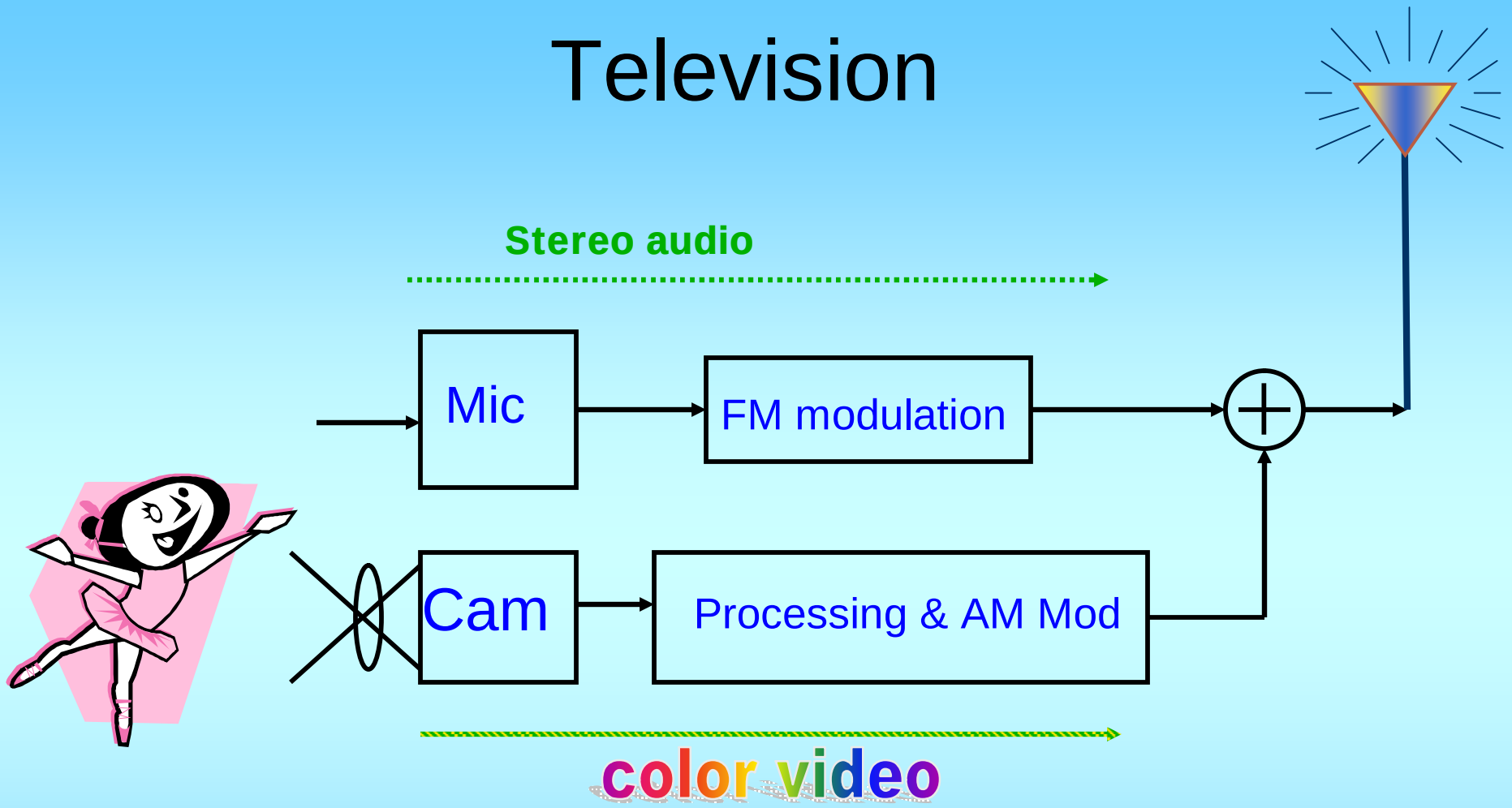
Now Back to old, existing

AM Radio

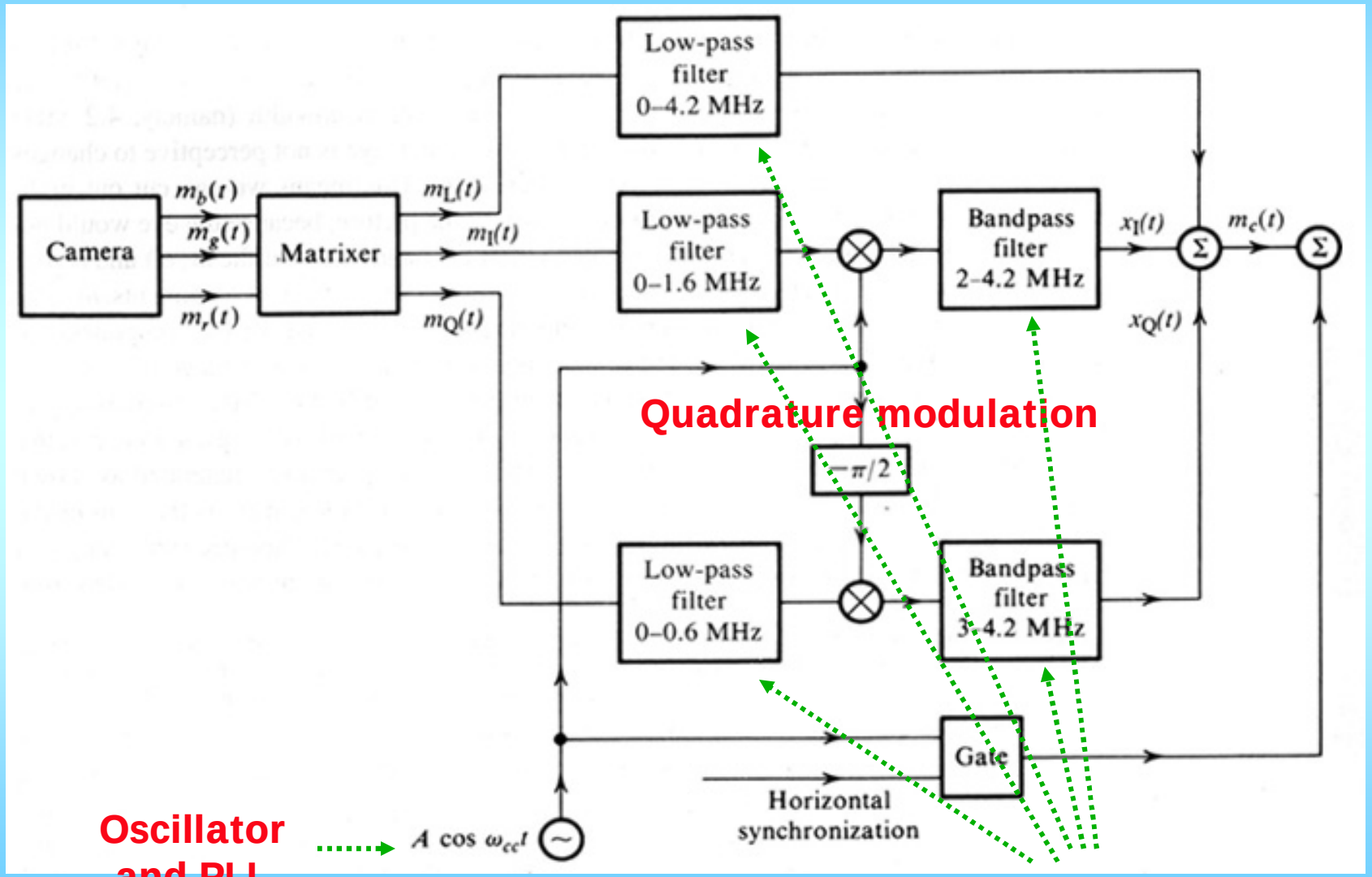


A. Input acquired from OSCILLATOR (1000 KHZ)
B. A 2nd signal from transducer is mixed with 1000 CW to produce an Amplitude Modulated (AM) signal or Carrier Transmission.

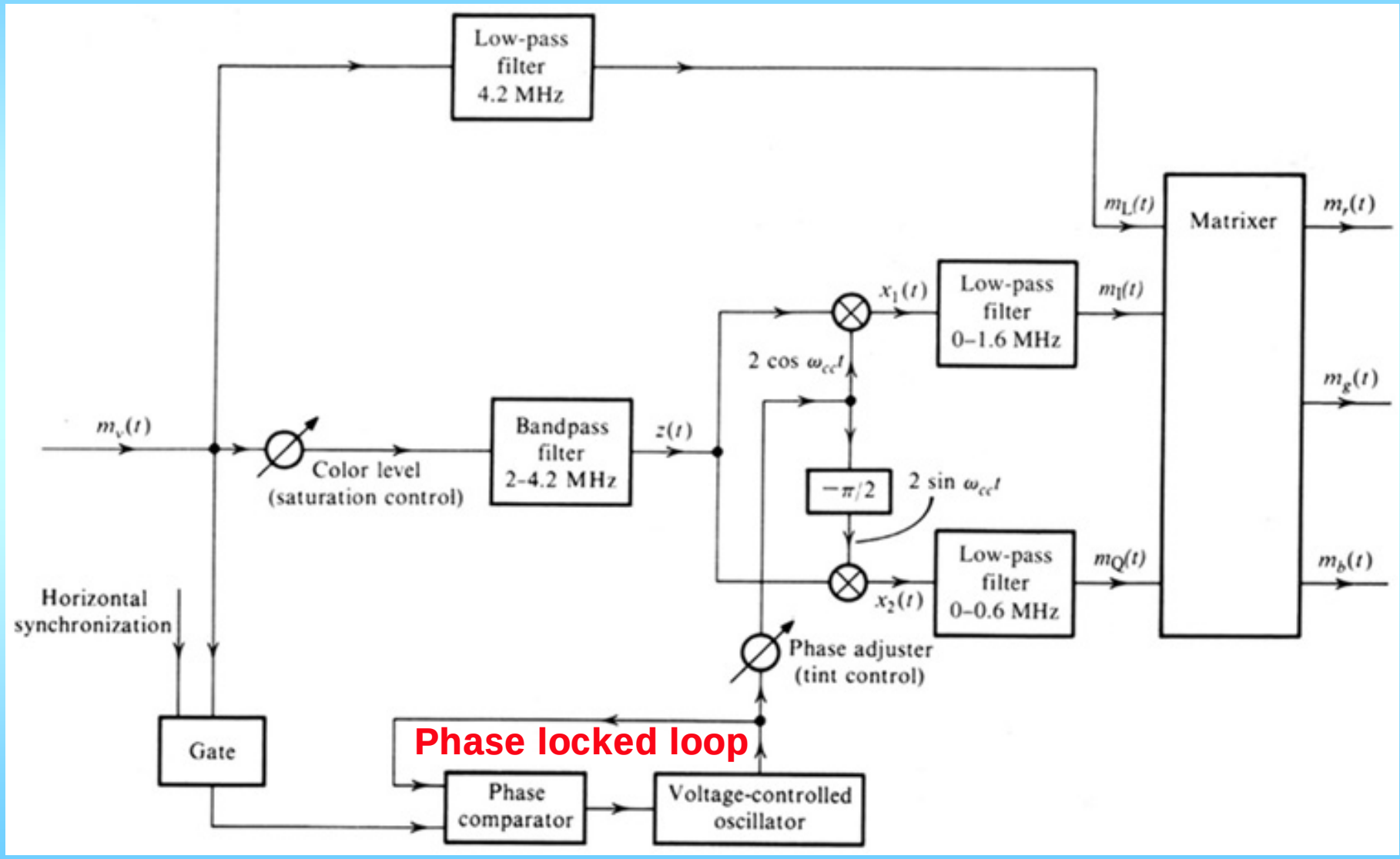
Television


Stereo audio
Mic
FM modulation
Cam
Processing & AM Mod
color video

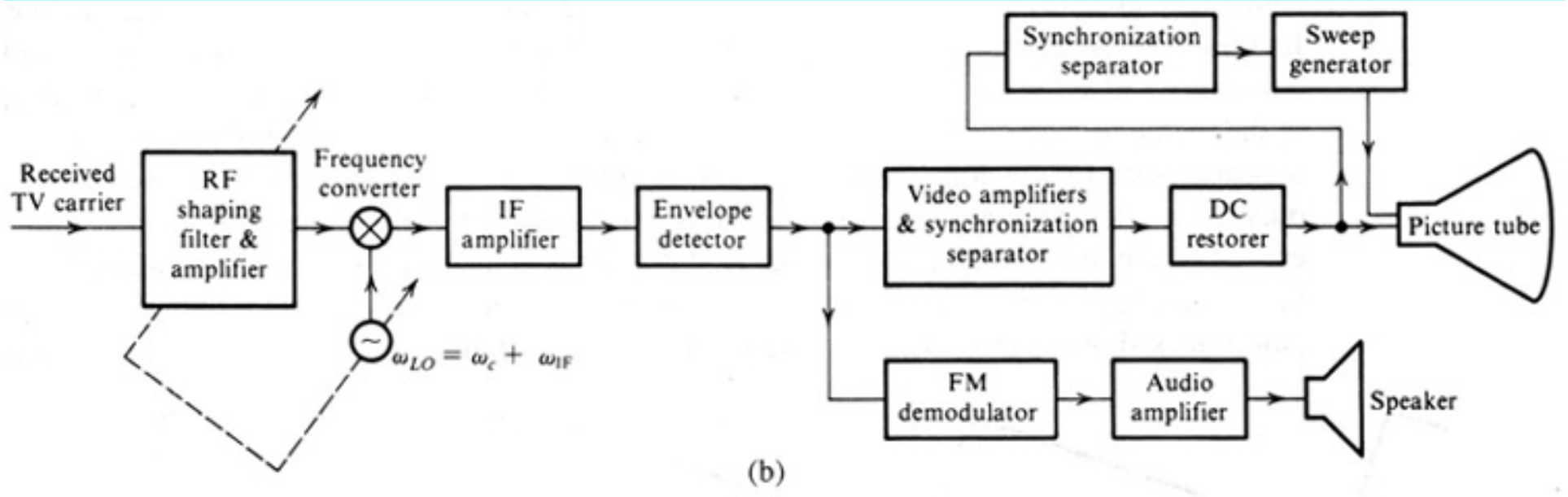
Video part


Low-pass filter 0–4.2 MHz
Camera
$m_b(t)$
$m_g(t)$
$m_r(t)$
Matrixer
$m_L(t)$
$m_I(t)$
$m_Q(t)$
Low-pass filter 0–1.6 MHz
Bandpass filter 2–4.2 MHz
$x_I(t)$
$x_Q(t)$
$m_c(t)$
Σ
Σ
Quadrature modulation
$-\pi/2$
Low-pass filter 0–0.6 MHz
Bandpass filter 3–4.2 MHz
Gate
Horizontal synchronization
$A \cos \omega_{cc} t$
~
Oscillator and PLL
A lot of filtering

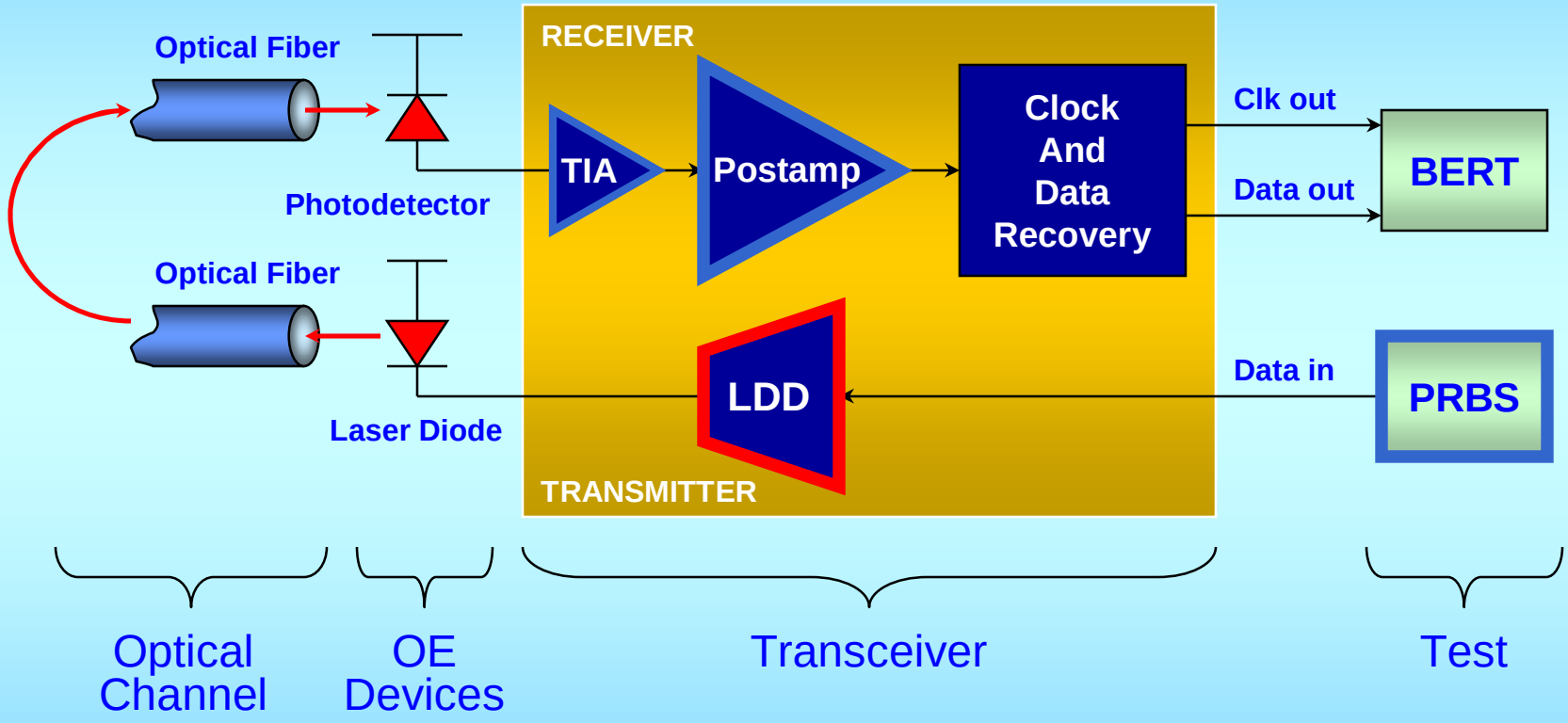
Video part


Low-pass filter 4.2 MHz
$m_L(t)$
Matrixer
$m_r(t)$
$x_1(t)$
Low-pass filter 0–1.6 MHz
$m_I(t)$
2 cos $\omega_{cc}t$
$m_g(t)$
$m_v(t)$
Color level (saturation control)
Bandpass filter 2–4.2 MHz
$z(t)$
$-\pi/2$
2 sin $\omega_{cc}t$
Low-pass filter 0–0.6 MHz
$m_Q(t)$
$m_b(t)$
$x_2(t)$
Horizontal synchronization
Phase adjuster (tint control)
Gate
Phase locked loop
Phase comparator
Voltage-controlled oscillator

TV receiver

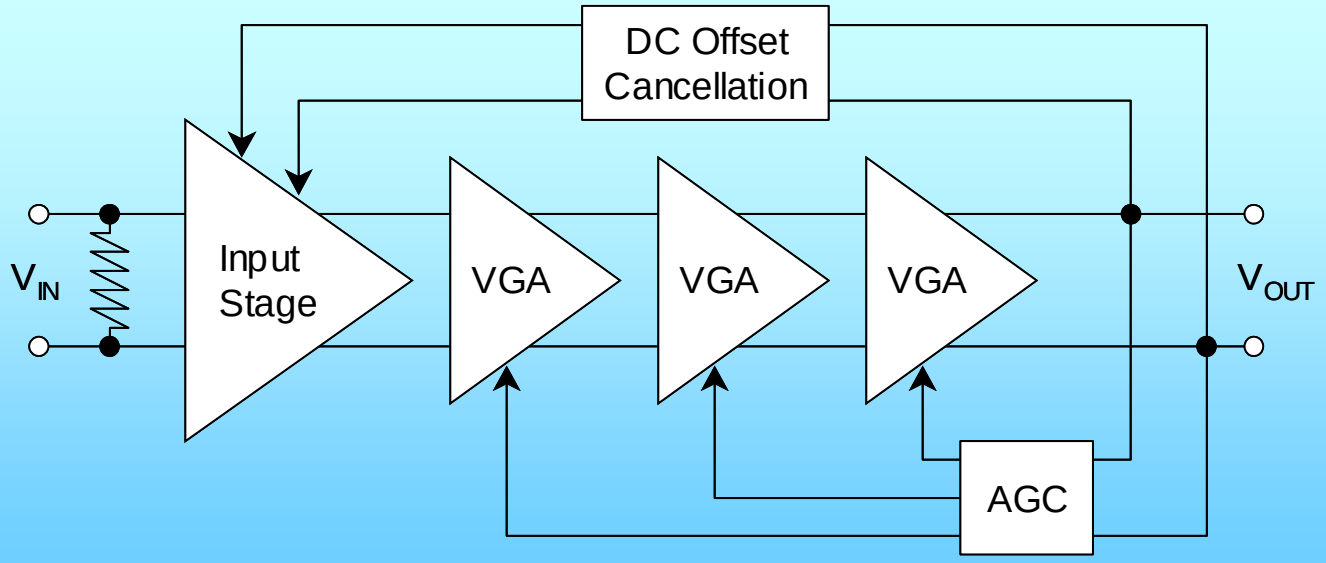

Synchronization separator
Sweep generator
Received TV carrier
RF shaping filter & amplifier
Frequency converter
IF amplifier
Envelope detector
Video amplifiers & synchronization separator
DC restorer
Picture tube
$\omega_{LO} = \omega_c + \omega_{IF}$
FM demodulator
Audio amplifier
Speaker
(b)

Optical Transceiver Architecture



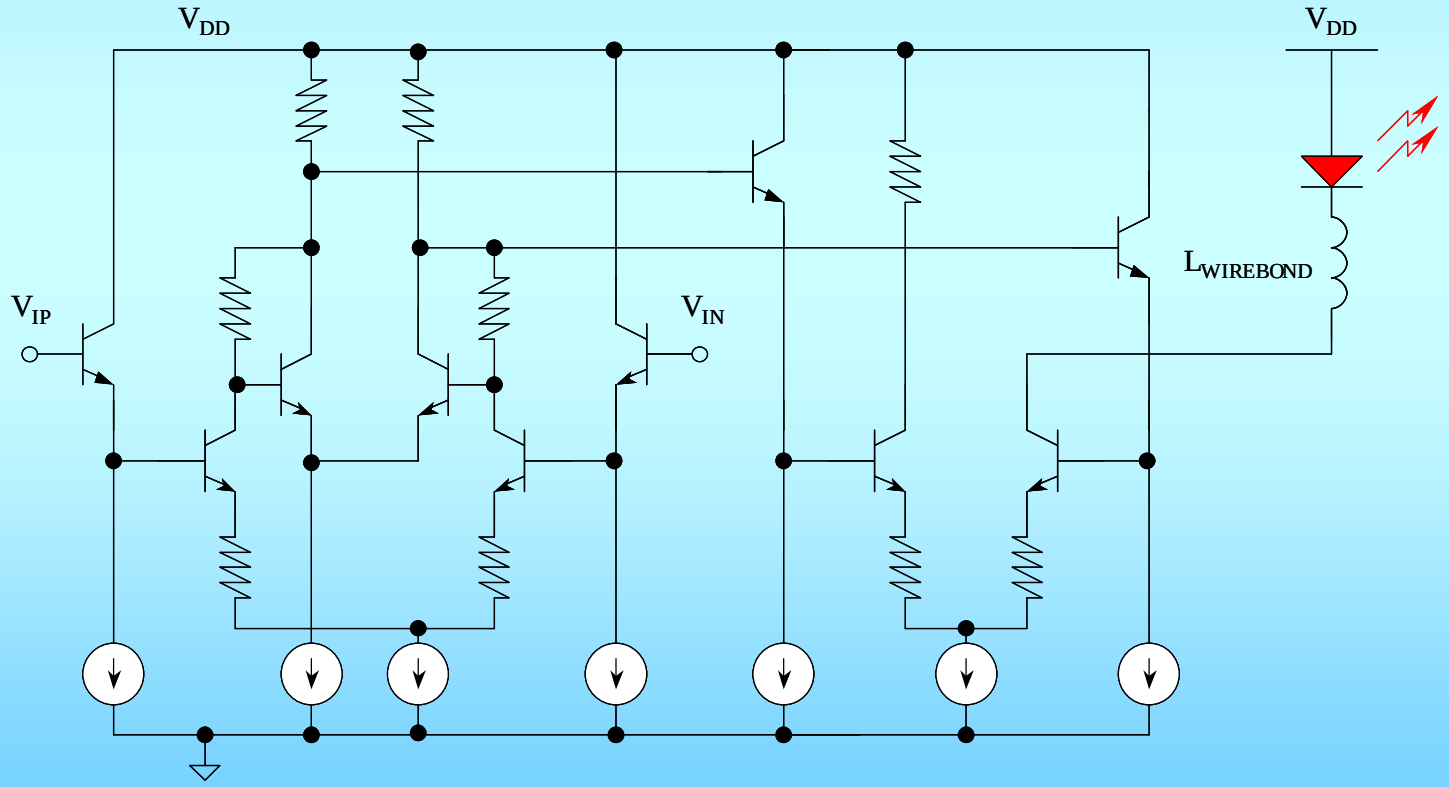
AGC Postamplifier

- Automatic gain control maintains gain stages in their linear region to reduce jitter
- Excess gain can be dynamically traded for additional bandwidth and better phase response
- Different gain control for each VGA stage to reduce noise



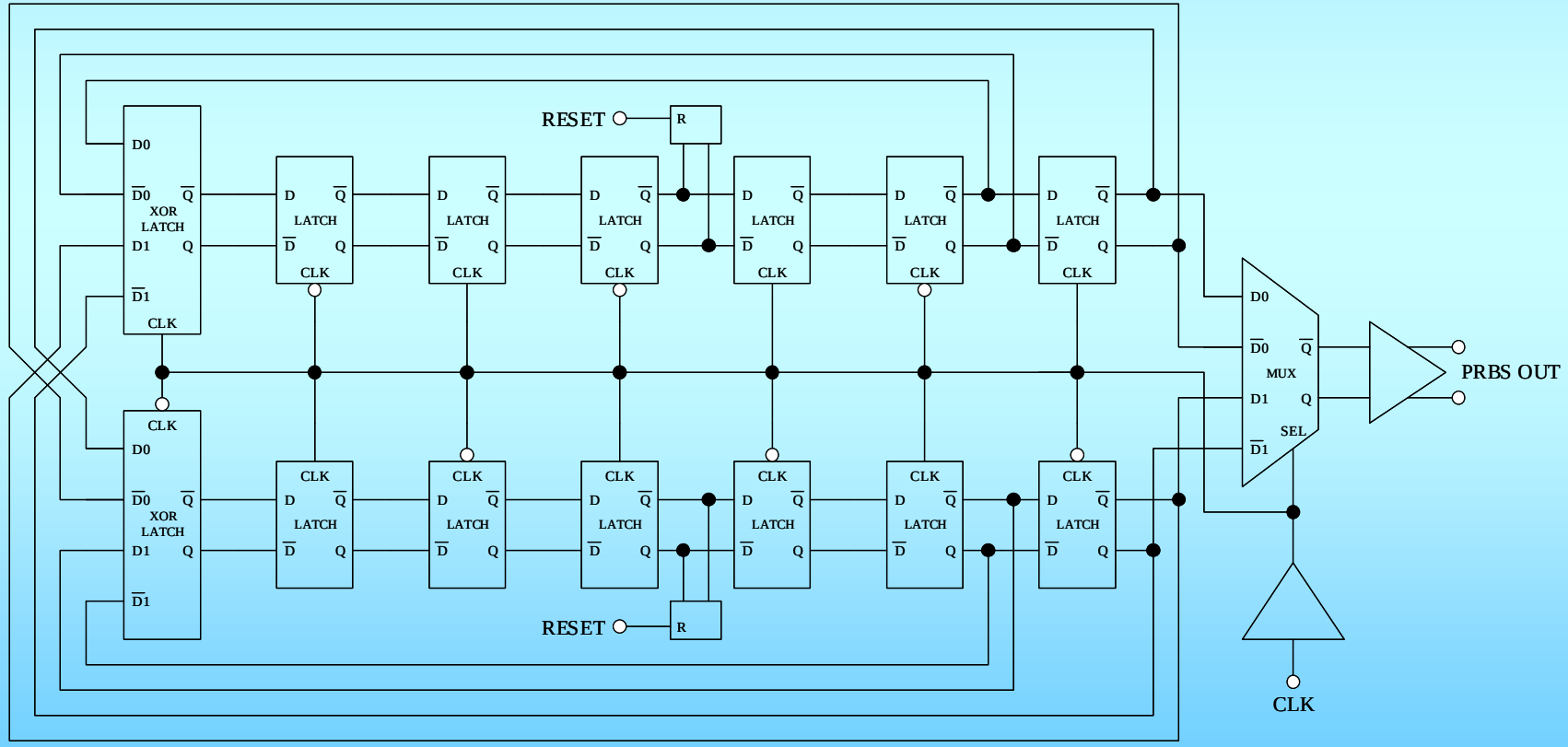
Laser Diode Driver

- Cherry-Hooper limiting preamplifier
- Transconductance amplifier output stage

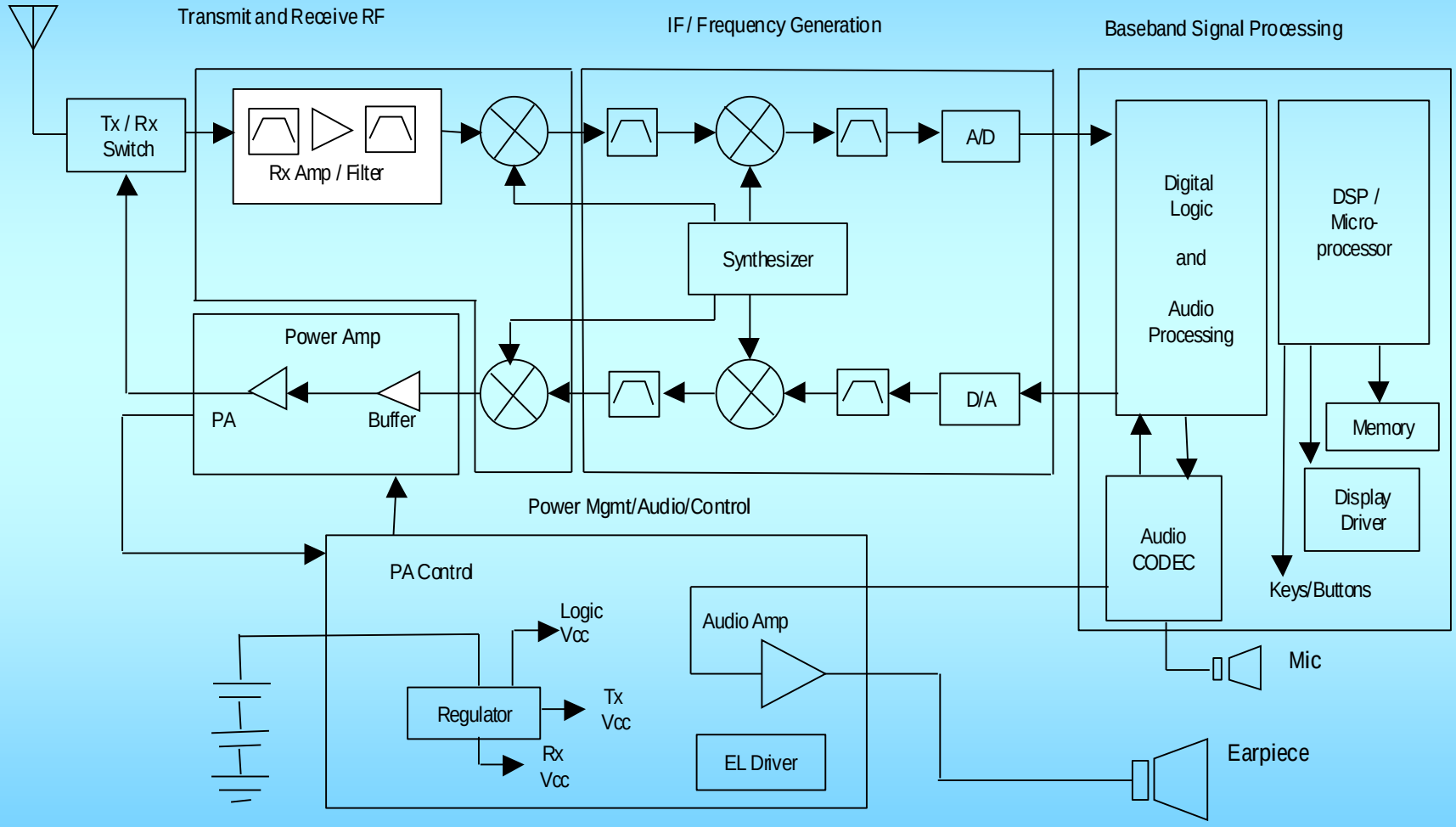


Interleaved PRBS Architecture

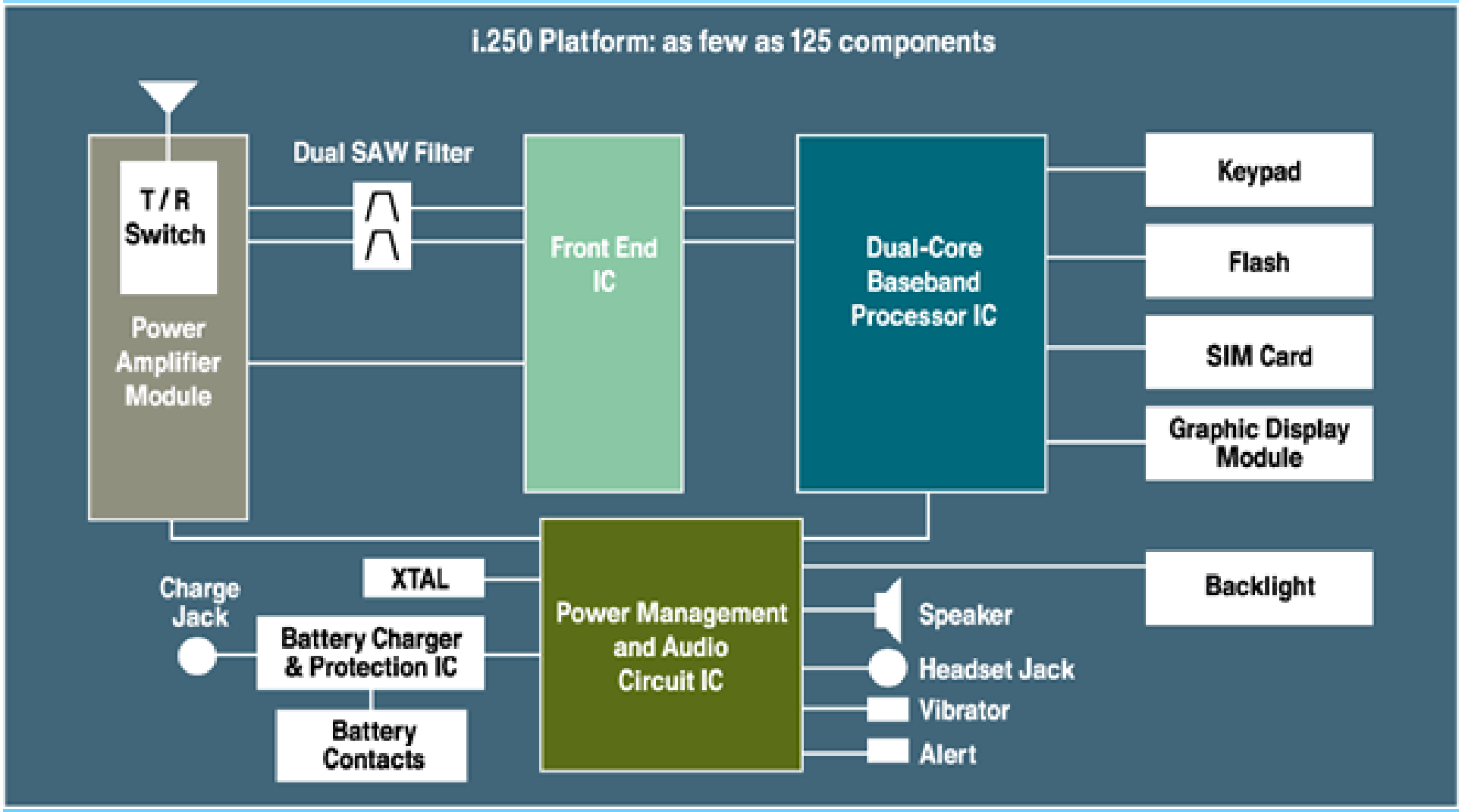
- The shift register operates at only half the data rate



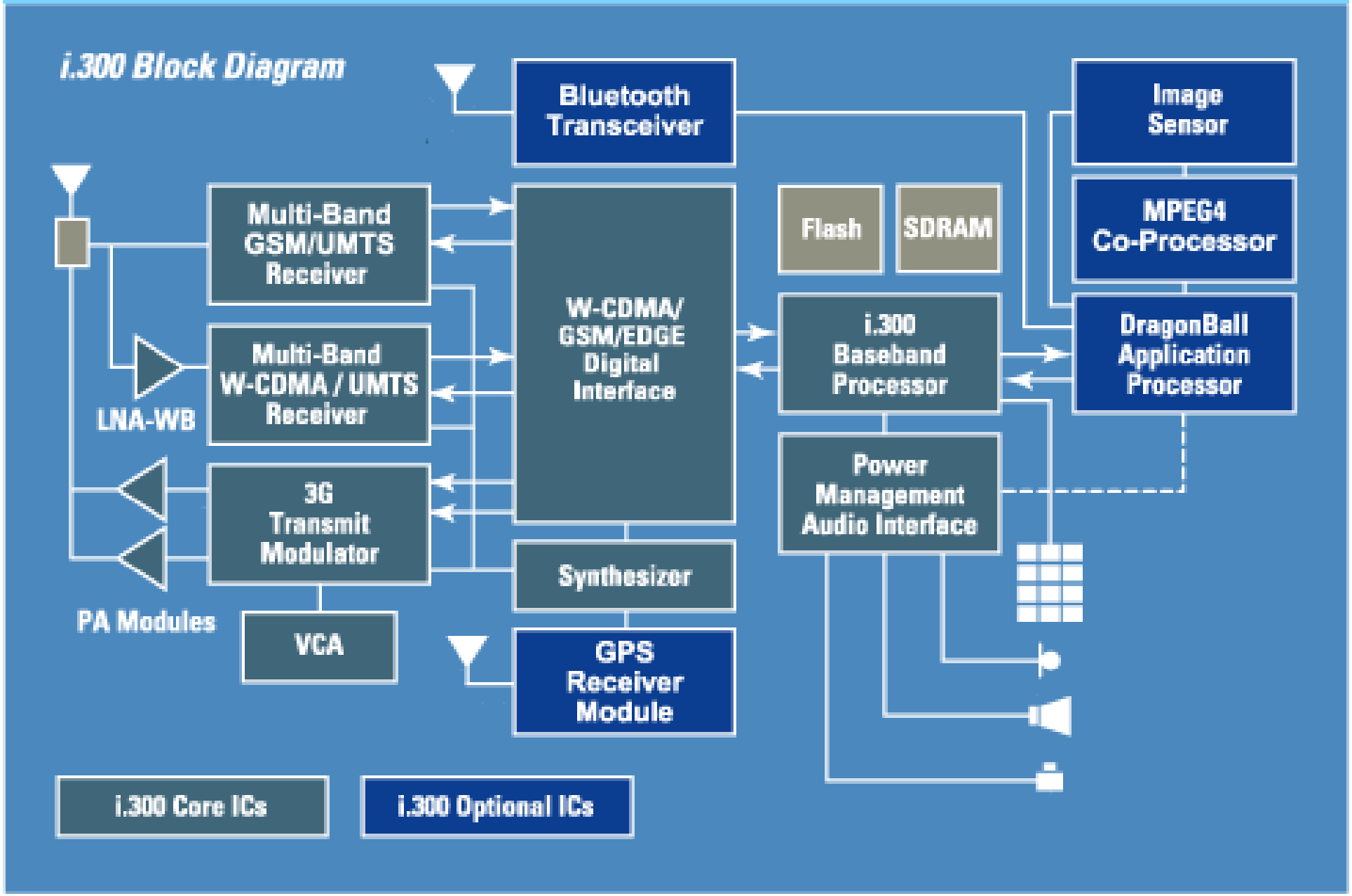
Generic Wireless Phone Block Diagram



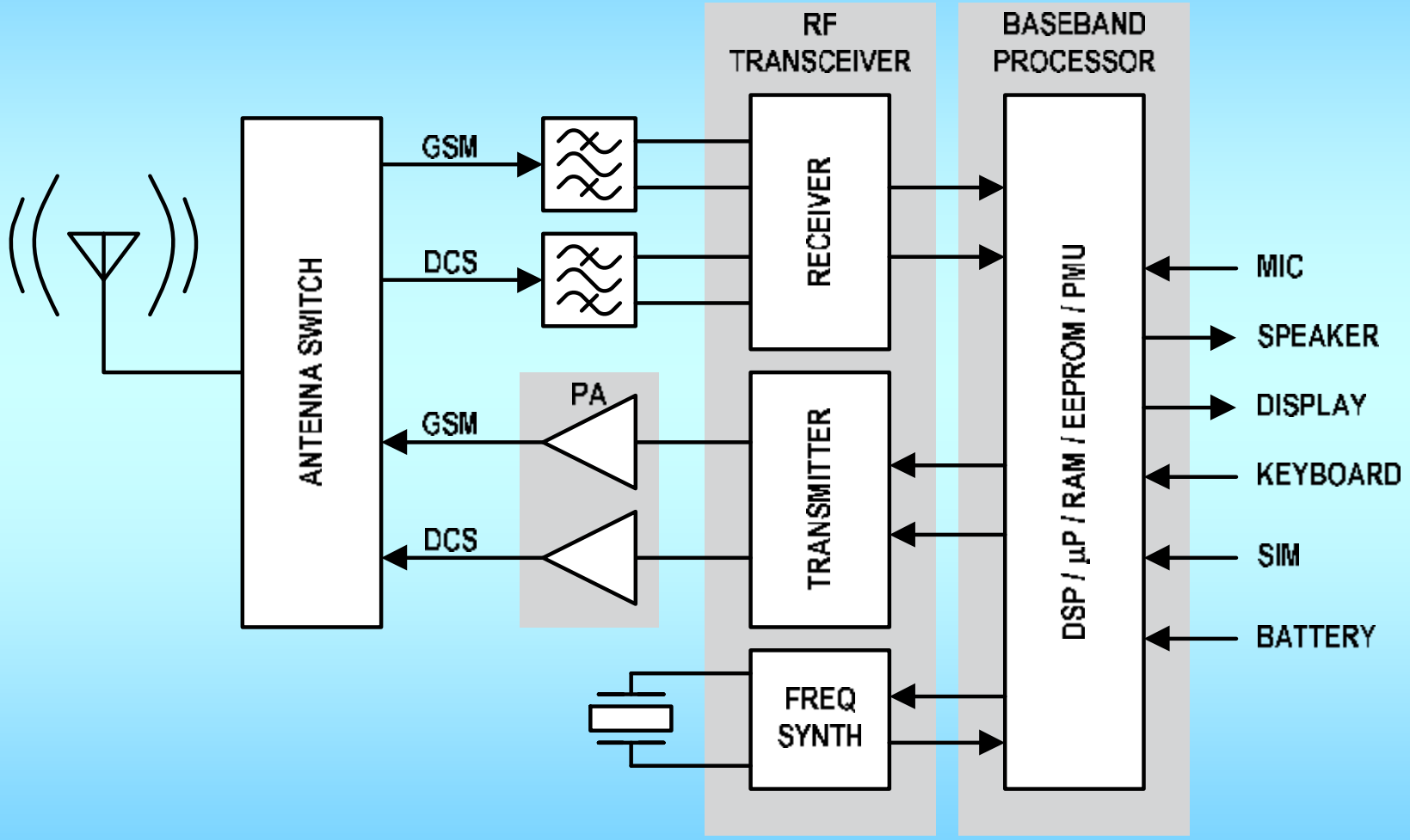
State-of-the-Art 2.5G Phone Architecture



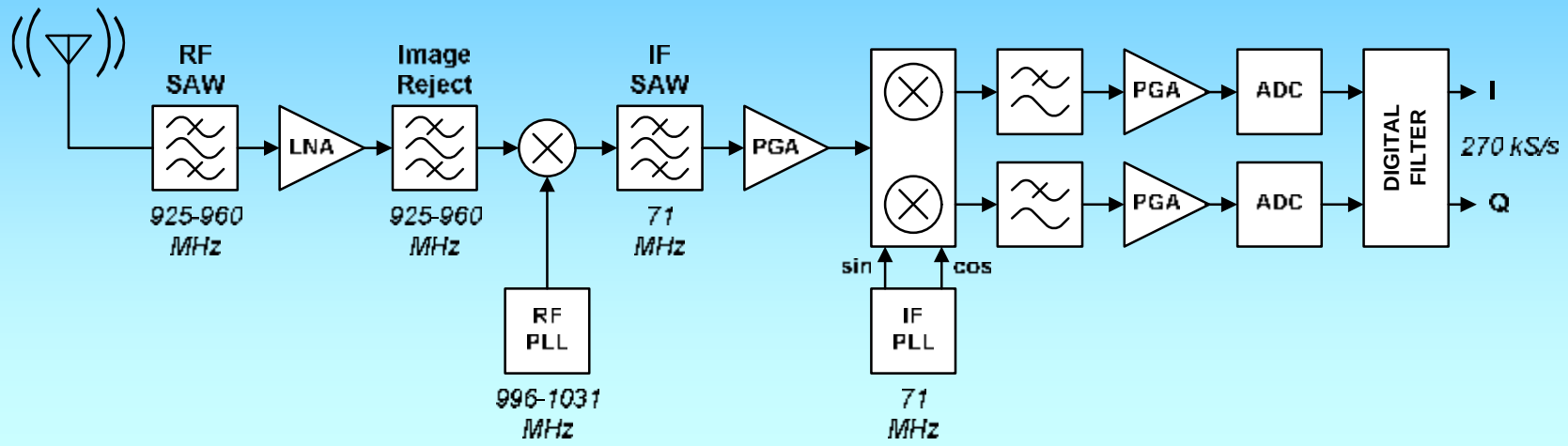
State-of-the-Art 3G Smart Phone Architecture



Functional block diagram



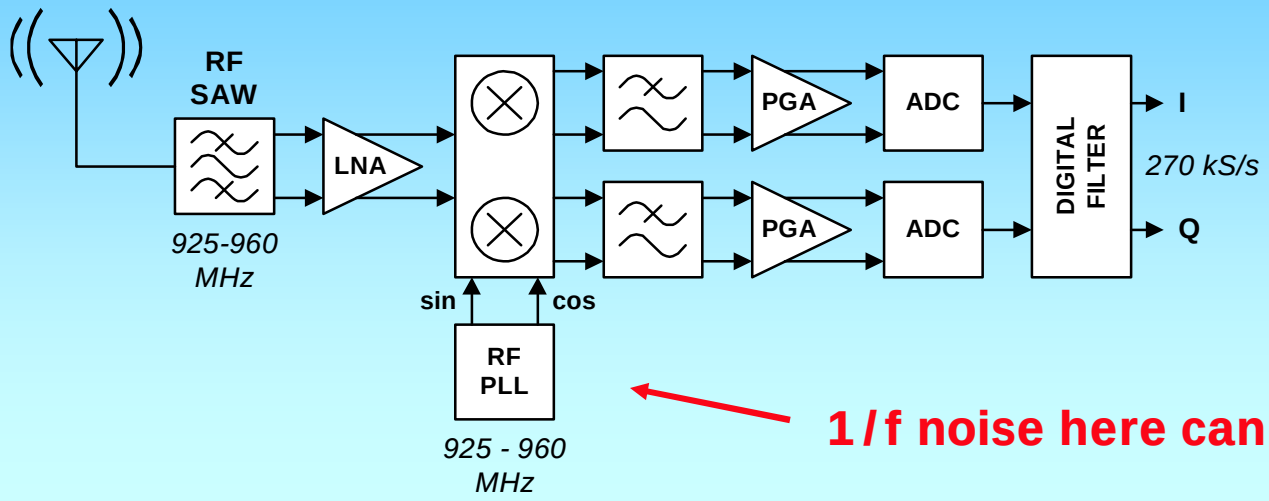
Superheterodyne Receiver



+ Best overall performance
+ Usually lowest power
+ Flexible frequency plan
+ Avoid DC problems

- Expensive, large
- many discrete, external components
- Image problem
Difficult for multi-mode (need multiple IF filters

Direct Conversion Receiver

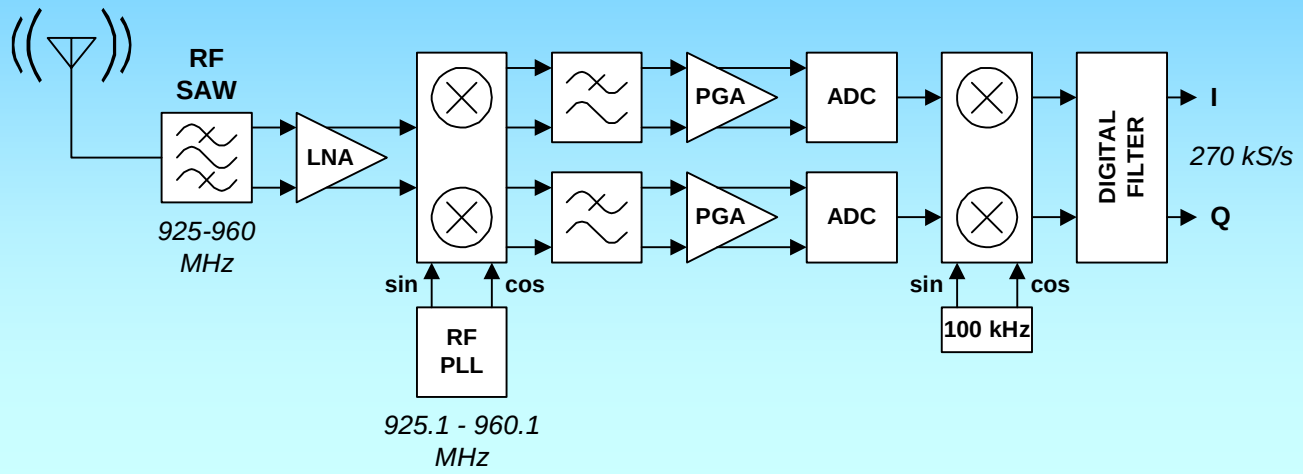


1/f noise here can end up in channel

+ Eliminate IF SAW, IF PLL and image filtering
+ Integration
+ Avoids image problem

- Quadrature RF down conversion required
- DC problem
- Typically requires offset or 2x LO to avoid coupling

Low IF receiver



+ Eliminate IF SAW, IF PLL and image filtering

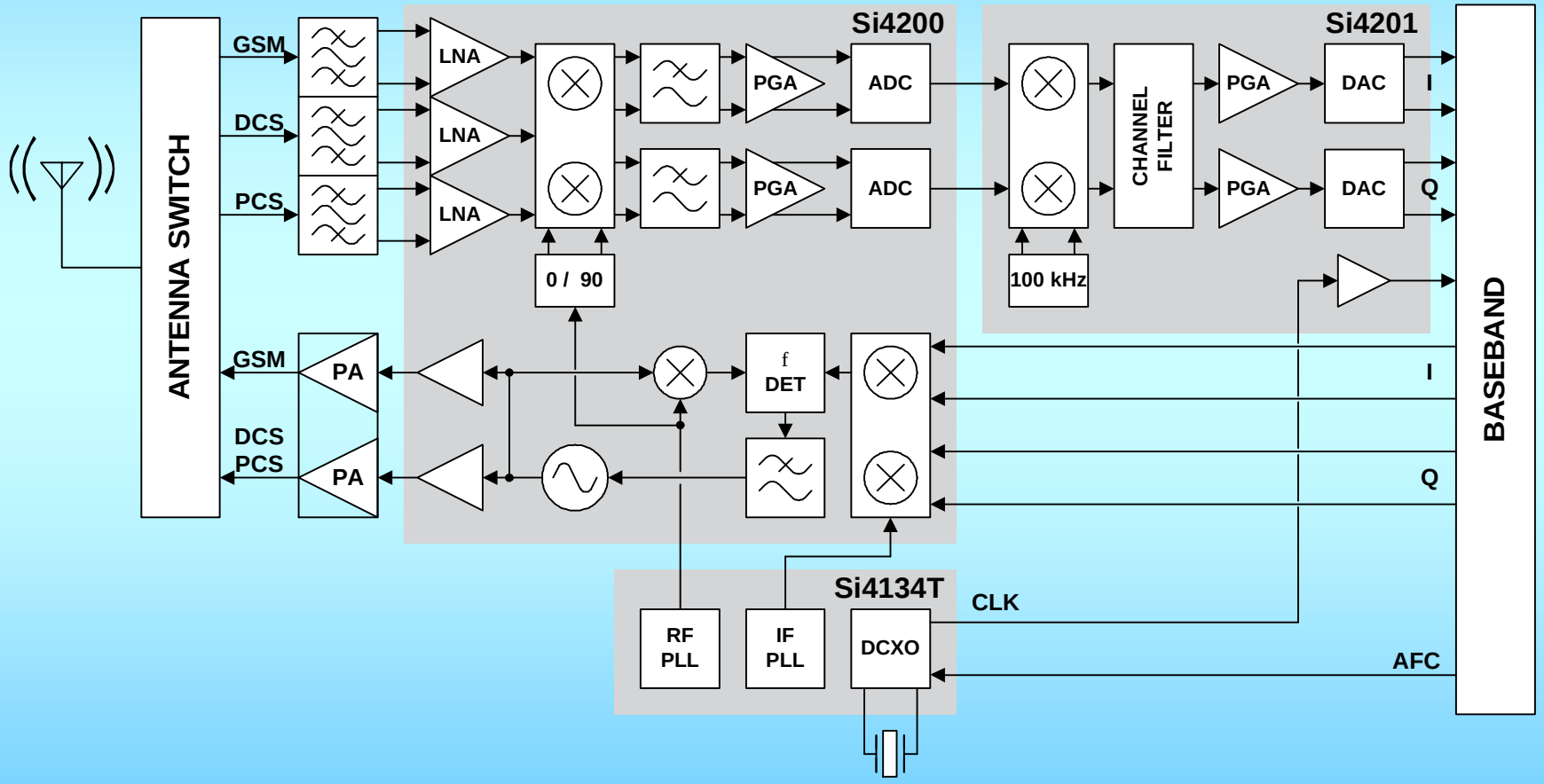
+ Integration

+ Relaxes image rejection requirements

+ avoids DC problems

- Quadrature RF down conversion required
- Require higher performance ADC
- Additional mixer
Slower RF PLL settling

CMOS transceiver architecture

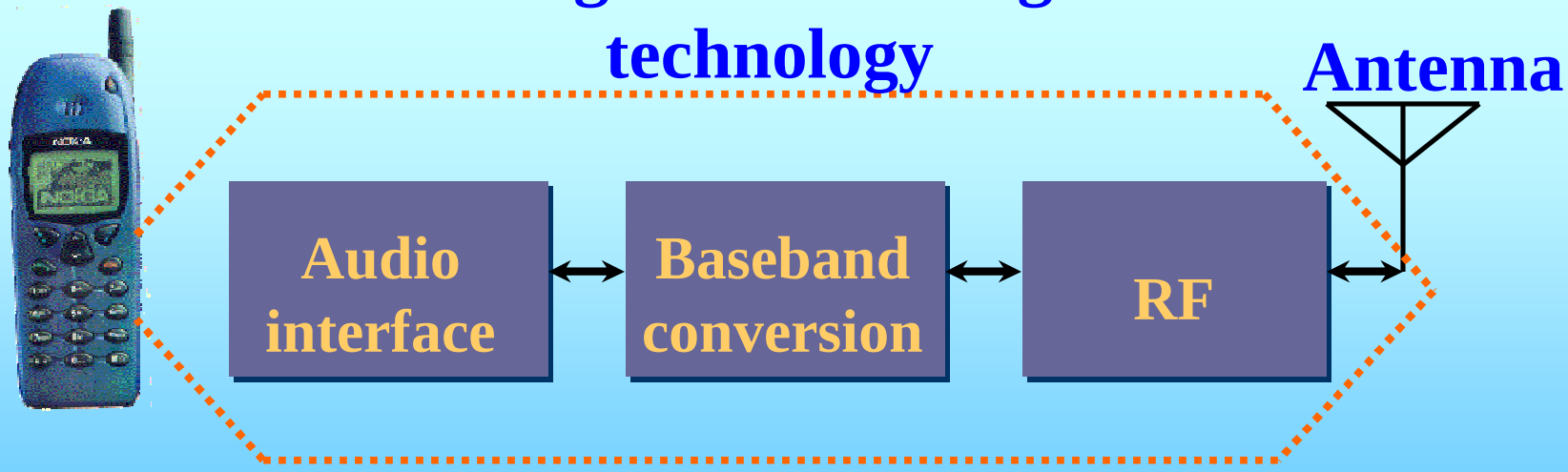


Our Focus is on VLSI Circuit Design

Cell phone example

Application in other communication systems

Analog and mixed-signal technology



Major components

- Antenna and interface
- RF input filter
- Low noise amplifier
- Mixer
- Oscillator
- Phase-locked loop
- Frequency synthesizer
- ADC/DAC
- Power amplifier

Performance Concerns

- DC offset
- Image rejection
- Quadrature requirements
- Noise and noise figure
- Phase noise and Jitter
- Distortion
  - Compression
  - Desensitization
  - Cross modulation
  - Intermodulation
  - IP2, IP3
  - Harmonic distortion (THD, SFDR,…)
- Bit error rate
- Data rate (bandwidth)